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EFFECTS OF SIMULATED AIRCRAFT NOISE ON HEART-RATE AND BEHAVIOR OF DESERT UNGULATES

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This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

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13. ABSTRACT *(Maximum 200 words)*

We evaluated the effects of simulated low-altitude jet aircraft noise on the behavior and physiology of captive desert mule deer (Odocoileus hemionus crooki) (n- 6) and mountain sheep (Ovis canadensis mexicana) (n -5). We measured heart rate, body temperature, and behavior in relation to ambient temperature, number of simulated overflights/day, and noise levels (range - 92-112 decibels [dB]) that the animals were exposed to. We compared heart rates during simulated overflights (n -112/treatments/season) to data collected prior to and following treatment periods. We documented differences between heart rates for animals, noise levels, and number of overflights between seasons. All animals became habituated to sounds of low-altitude aircraft. Although heart rates increased during overflights, they returned to resting rates in ≤ 2 minutes.

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PREFACE

In 1988 the United States Air Force (USAF) decided they needed more information to understand if and how noise from low-altitude jet aircraft influenced wildlife. To that end we began a series of studies to document the influence of noise from low-altitude jet aircraft on habitat use, behavior, and heart rate of desert mule deer (Odocoileus hemionus crooki) and mountain sheep (Ovis canadensis mexicana).

The first study was conducted at the Agriculture Research Center, University of Arizona, Tucson. We designed a pen for 4 desert mule deer and 4 mountain sheep and subjected them to recorded noise from low-altitude jet aircraft. We monitored their behavioral and physiological responses to the stimuli and developed technology to apply similar stimuli to free-ranging animals. This report presents our results and is the first of 2 reports to be prepared under the contract. The second report will document the influence of low-altitude jet aircraft on semi-free ranging mountain sheep.

Our intent is to provide data that are useful for land managers and the USAF to be able to make informed decisions regarding USAF aircraft and their influence on wildlife. As more demands are being placed on wildlife and their habitats these are part of the data needed for management.

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Numerous people were responsible for the completion of this study. S. Cameron and E. Patula, University Medical Center, University of Arizona, were instrumental in animal surgery and care. S. Albert and J. Weisenberger assisted with maintenance of captive animals. R. C. Kull, Wright Patterson Air Force Base; T. D. Bunch, Utah State University, Logan; and A. E. Bowles, Hubbs' Sea World Research Institute, San Diego, California reviewed earlier drafts of this work. V. Catt typed numerous drafts. The project was funded by the United States Air Force and administered by the United States Fish and Wildlife Service, and the School of Renewable Natural Resources, University of Arizona. To these and all others involved in this effort many, many thanks.

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1. INTRODUCTION

One role of the U. S. Air Force (USAF) is to train pilots for national defense. The rigorous demands placed on military tactical aircrews to maneuver high speed aircraft along carefully planned routes, taking advantage of terrain to avoid detection by defensive forces, require frequent training to maintain proficiency (Holland 1991). Low altitude military training flights ($\leq$419 m above ground) are regulated by the Federal Aviation Administration and the Department of Defense. Two types of air space (i.e., special use and military training routes), are designated to minimize impacts with other air space users. Developing new low level training routes or changing air space designation requires compliance with the National Environmental Policy Act and environmental impact assessment guidelines. Most air space designations were made in the 1950-60's (Holland 1991). More recently, public lands underlying the military designated air spaces have been set aside as national parks, wildlife refuges, or wilderness areas to be preserved for public enjoyment (Holland 1991); should flights over them be restricted?

Human encroachment and development has altered wildlife habitat on private and federal lands throughout the United States (Leslie and Douglas 1980, Etchberger et al. 1989). Recently, wildlife managers have expressed concern about the influence of aircraft noise on ungulate populations (Asherin and Gladwin 1988). For example, the General Accounting Office (GAO) reported that overflights at the Cabeza Prieta National Wildlife Refuge (NWR), Arizona may harm mountain sheep (*Ovis canadensis*) and Sonoran pronghorn antelope (*Antilocapra americana sonoriensis*). The Kofa NWR in western Arizona does not permit military flyovers below 458 m (M. Haderlie, U. S. Fish and Wildl. Serv., pers. commun.; Gladwin et al. 1988).

Several studies have examined the behavioral and physiological effects of sonic booms (see Appendix A for definitions of terms)

on domestic animals (Bell 1971, Bond et al. 1974, Espmark et al. 1974, Ewbank 1977, Manci et al. 1988). Subsonic aircraft can also affect wildlife; Espmark et al. (1974) reported that domestic animals responded more intensely to low-altitude aircraft noise than to sonic booms. Reindeer (Rangifer tarandus) exhibited strong panic responses to fixed-wing aircraft flying ≤152 m but did not respond as strongly to helicopters (Calef et al. 1976). Fixed-wing overflights (Cessna 172, 182 aircraft [Krausman and Hervert 1983]) ≥100 m above ground did not disturb mountain sheep in Arizona. However, Stockwell et al. (1991) studied mountain sheep in the Grand Canyon, Arizona and reported that in winter mountain sheep foraged less efficiently in the presence of helicopters than when helicopters were absent. In addition, Bleich et al. (1990) reported that mountain sheep moved 2-5 times farther the day following a helicopter survey than on the previous day and changed home-range polygons by 8-83 km following helicopter surveys. When aircraft (i.e., helicopters) fly close to the ground (≤100 m) they may create more disturbances than higher flying aircraft. Krausman et al. (1986) reported that desert mule deer (Odocoileus hemionus crooki) in south-central Arizona changed habitats in response to low-altitude aircraft (<100 m) but did not change habitats when aircraft flew >100 m above them.

Domestic animals and wildlife initially respond to aircraft noise with a startle reaction. Sporadic jumping, galloping, bellowing, and haphazard movement were a few responses of large farm animals observed by Cottereau (1978). Harrington and Veitch (1991) reported low jet overpasses "... indicated an initial startle response but otherwise brief overt reaction by woodland caribou [Rangifer tarandus] on late-winter alpine tundra habitats." These behavioral responses to noise have caused secondary injuries in domestic animals (e.g., broken legs [Cottereau 1978]), and may cause stampedes in wild animals that could result

in drowning and trampling (Sinclair 1979) or other forms of mortality (Harrington and Veitch 1991).

Animals react differently to sound intensity and duration (Ames and Arehart 1972, Borg 1981), and direction (Tyler 1991). Ames and Arehart (1972) investigated the effects of intermittent bursts of white noise, music, and miscellaneous sounds from 75 to 100 dB. Habituation to intermittent sounds was gradual and minimal in each of the experiments.

Habituation to intermittent sounds $\geq$75 dB is gradual (Ewbank 1977, Espmark and Langvatn 1985). However, an array of studies with laboratory animals (i.e., rodents [Borg 1979]), domestic animals (i.e., sheep [Ames and Arehart 1972]), and wildlife (e.g., elk [Cervus elaphus] [Espmark and Langvatn 1985]) have shown that animals can become habituated to noise.

The effects of noise from low-altitude subsonic aircraft on animals have not been studied extensively. In many studies (Krausman and Hervert, 1983, Krausman et al. 1986, Bleich 1990, Stockwell et al. 1991), the response of wildlife to aircraft was documented but the noise levels generated by aircraft were not measured.

Military overflights concern land managers (e.g., U. S. Fish and Wildl. Serv., Nev. Dep. Wildl.) because the unknown effects of auditory and visual stimuli from jet aircraft are a potential threat to wildlife populations. How animals respond to aircraft noise can be important in management decisions about U.S. Air Force use of air space and wildlife subjected to overflights.

In response to the need for more information about the effects of overflights on wildlife we describe how desert mule deer and mountain sheep respond to controlled noises created by low-altitude military jets. We document the changes in heart

rates and behavioral responses to examine 2 questions. Does low-altitude aircraft noise alter the behavior of desert ungulates, and does low-altitude aircraft noise create a chronic increase in heart rate?

2. STUDY AREA

We conducted the study on the University of Arizona Agricultural Research Center, Tucson, Arizona. The animals were enclosed in outdoor chainlink 6-X-15 m pens (2 animals/pen) (Fig. 1). We fed animals alfalfa hay, mixed grain, supplemental salt, and water ad libitum. We attached sheets of 6.35 mm water-proof treated plywood and gypsum boards to the entire east-facing side of the experimental pens to decrease all background and uncontrolled noise to an average sound pressure level of 45 dB.

The animals were free to move about in the pens during the study. They always were visible from a 2.4-X-6.0-m observation center located 10.0 m west of the experimental pens.

Reflective film was placed on all windows of the observation center to allow free movement by observers without distracting the animals. We housed measurement equipment in the observation center. The speaker used to simulate aircraft overflight noise was secured at a 41.5° angle directed toward the pens on the top of a 6.0-m scaffold 1.0 m south of the pens (Fig. 1).

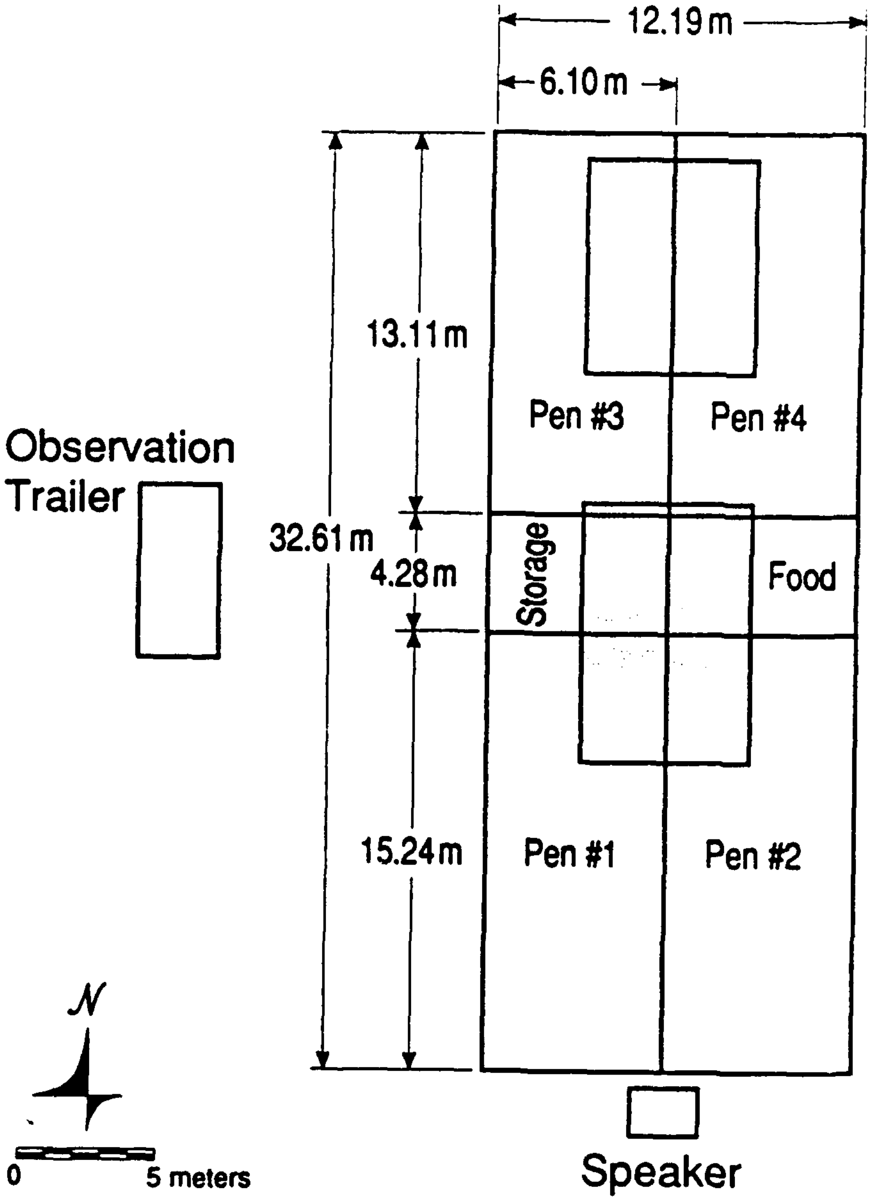

Figure 1. Design of Study Enclosure in Tucson, Arizona. Shaded Areas are Ramadas for the Animals.

3. METHODS

We used 5 captive-born mountain sheep (3 M, 2 F) and 6 captive-born desert mule deer (6 M). At the time of the experiment, the sheep and deer were 1-3 and 2-6 years old, respectively. All uses and care of captive animals followed guidelines established by the American Society of Mammalogists (1987), and the Institutional Animal Care and Use Committee, University of Arizona.

Fluctuations in heart rate are a sensitive indicator of responses to an array of stimuli (MacArthur et al. 1979, Nilssen et al. 1984, Fancy and White 1986) in ungulates. Heart rate varies with level, intensity, duration, and probably frequency of auditory stimuli (Ames and Arehart 1972). Heart rate telemetry experiments have determined some forms of stimuli in animals that intensify cardiac response in relation to behavioral activities (Ames and Arehart 1972; MacArthur et al. 1979, 1982).

We measured physiological parameters by implanting heart rate monitors (J. Stuart Enterprises, Oceanside, Calif.) in experimental animals following surgical procedures described by Bunch et al. (1989). The heart rate monitors, encapsulated in a paraffin and Elvax vinyl compound, were designed for > 1 year battery life and $\leq$ 1 km transmitter range.

We captured the penned animals with a throw-net, jab stick, or Crossman CO_2 dart gun. We sedated animals for surgery by intramuscular administration of a sedative dosage (100 mg/mL) of xylazine hydrochloride (HCl) and ketamine HCl.

We determined the accuracy of the heart rate transmitter during surgery by comparing the transmitted heart rate with ECG results (Hewlett-Packard Model 7830A) (Pauley et al. 1979, Cassirer et al. 1988). The aseptic surgical procedure lasted 1.0-1.5 hours. During surgery we intubated animals and anesthetized them with

halothane. Following surgery, animals were immediately transported to the experimental pens where yohimbine HCl, doxapram HCl, and/or naloxone HCl was intravenously administered to reduce the effects of the capture drugs and surgical anesthetic (Franzmann and Lance 1986). Animals resumed maintenance behavior $\leq$ 10.0 minutes following injection. All animals were observed for several hours after reversal to document any complications that may have developed.

The heart rate transmitters measured approximately 40.0 mm in diameter and 65.0 mm in length, and weighed 170.0 g. A radio frequency pulse was transmitted for each depolarization of the ventricles detected (Kreeger et al. 1989), so that the biologist received a signal similar to a tracking signal (Pauley et al. 1979) transmitted by radio collars. Heart rates, detected with a Telonics (Mesa, Ariz.) TR-2 receiver, were expressed as beats/minute (bpm) and calculated from 15 second counts taken while the animals were engaged in active (e.g., walking, standing, running), and inactive (e.g., bedding) behaviors. Concurrent active behaviors recorded included foraging and other active (e.g., drinking, defecating, urinating, play, dominance, and reproductive) behaviors. Concurrent inactive behaviors recorded were ruminating, panting, and changing bedding positions. An activity had to persist for 15 seconds before we recorded heart rate for that activity during baseline periods. We recorded heart rates for all specified behaviors, regardless of duration, during treatment periods.

Low-altitude aircraft noise was simulated using a digital sound system designed and installed on the site by Acentech Inc. (Chavez et al. 1989) (Appendix B). The system produced 7 different signals simulating overflights from B-1B and F-4D aircraft (Table 1). The overflights had onset rates from 10.1 to 45.6 dB/second and maximum A-weighted sound pressure levels from

Table 1. Simulated Low-Altitude Aircraft Noise Used at the University of Arizona, Tucson, 1990-1991.

Overflight number	Overflight descriptions				Noise descriptions		
	Aircraft type	Altitude (m)	Offset (m)	Speed (knots)	Onset (dB/sec)	L_{eq} [a]	L_{max} [b]
1	B1-B	317	312	578	10.7	92.5	101.0
2	B1-B	316	6	578	17.9	96.3	108.1
3	B1-B	166	18	575	27.0	100.0	112.2
4	F-4D	33	620	534	10.1	83.8	92.5
5	F-4D	465	11	561	20.2	94.9	107.2
6	F-4D	238	9	586	33.8	99.5	109.3
7	F-4D	157	17	592	45.6	99.3	108.8

[a] L_{eq} = mean dB level for time that sound exceeded 70 dBA.

[b] L_{max} - Maximum A-weighted sound level in exposure zone 1 produced by overflight simulation.

92.5 to 112.2 dB. A simulation event is defined as each time a signal is played simulating a low-altitude aircraft overflight.

Four experimental pens (Appendix B, fig. 4) housed 2 conspecifics/pen. The pens were constructed and calibrated to the simulated overflights to expose animals to 5 different noise levels during each simulation event (Appendix B, tables 2, 3, 6, 7, 8). Pen design and facilities allowed for continuous remote monitoring of the behavioral and physiological responses of these desert ungulates to aircraft noise. Prior to the study, we kept the animals in the experimental pens for $\geq$4 weeks prior to any data collection to insure the animals were accustomed to the new pens and had recovered from surgery.

The experiment was conducted in 3 seasons: summer (12 May-9 Aug), late summer (13 Aug-12 Oct), and spring (4 Feb-5 Apr). Each season lasted 63-88 days. The experimental treatment exposed animals to 1 simulation event/day for days 1-7 and 22-28, and 7 simulation events/day for days 8-21 of the treatment period (Appendix C). We randomly selected simulation events, times, and individual animals observed during diurnal hours. The interval between each simulation event during the 7 events/day period was $\geq$ 1 hour to allow heart rate and behavioral data collection before and after each simulation event. We recorded data for 30 days prior to (pre-) and 7-30 days after (post-) each 28-day treatment period (Appendix C). Baseline data were collected during the pre- and post-periods using scan sampling (Altmann 1974). We used focal animal sampling (Altmann 1974) during treatment periods. In summer we also monitored behaviors continuously with a closed circuit video tape recording system. In spring, 1 mountain sheep and 2 mule deer were replaced with animals that had not been previously exposed to overflights or simulations. These naive animals were used to examine individual habituation to aircraft noise.

We analyzed observations from baseline and treatment periods to determine if there were long-term behavioral changes in response to simulated overflight treatments. We compared the percent of observations (baseline scans) in each behavior class between pre- and post- treatment periods, and among animals, and seasons with Chi-squared analyses. We calculated the length of time spent in each activity during treatment periods from continuous focal animal sampling. Percent of time spent in each behavior class during treatments was compared with Chi-squared analyses and the mean duration of each activity in a behavior class was compared with analysis of variance (ANOVA).

Behavioral responses of animals to simulation events were categorized based on overt behavior (modeled from Hicks and Elder 1979). We recorded no response when overt behavior did not indicate awareness of the stimuli. Alerted response was recorded when animals exhibited alerted behavior (e.g., looked toward or directed their ears toward the speaker), but did not alter their activity. For example, a bedded animal remained bedded after the simulation event, but directed its attention toward the speaker for some length of time. Alarmed responses were recorded when animals exhibited a startle or alarm behavior, looked toward the speaker, with ears directed toward the speaker, and altered their activity. For example, a bedded animal was startled, stood up, perhaps ran away from the speaker and directed its attention toward the speaker for some length of time.

We examined the relationships between cardiac response and behavioral patterns to aircraft noise. The mean heart rate was determined for pre- and post- periods and heart rates were compared among behaviors, species, and seasons using Student's *t*-test and Mann-Whitney U tests, depending upon the data available (i.e., with <30 samples we used Mann-Whitney U tests).

Animals' responses to the simulated overflights were analyzed using a repeated measures analysis of variance (MANOVA) (PROC GLM [SAS Inst. Inc. 1985:433]). Five measurements of heart rates for each observed simulation event were used for these analyses: 1 minute preceding the overflight (hr1), the actual time of overflight (hr2), and the first (hr3), second (hr4), and third (hr5) minutes proceeding each overflight. We used Wilk's lambda (PROC GLM [SAS Inst. Inc. 1985:433]) to compare heart rate measurements among individual animals, types of overflights, and noise level exposure based on calibrated area of pen in which animals were located during simulation events (Appendix B, fig. 4). The criteria for rejection of a statistical test was $\underline{P} > 0.05$.

4. RESULTS

No deaths or injuries to animals resulted from the surgical procedures or experimental treatments. Heart rate transmitter failures, due to lead breakage and body fluid leakage into transmitters (Wallace et al. 1992) during season 2 limited heart rate recordings. However, behavioral observations were collected as in other seasons.

There were significant differences in HR and behavior among individuals responding to noise. However, general trends were apparent.

We compared mean heart rates for mountain sheep (Table 2) and desert mule deer (Table 3) for pre- and post- periods and by behaviors and seasons (Table 4). Heart rates for all 3 periods increased as activity changed from bedding to foraging, walking, or running. Mean heart rates were significantly higher ($P < 0.05$) during the post- period for mountain sheep standing, foraging, and other active behaviors in summer and spring and were also higher for bedding in spring. Heart rates for desert mule deer bedding, standing, foraging, and other active behaviors were higher during summer post- treatments. Standing, foraging,and other active behavior heart rates were higher for mule deer in late summer post- treatments. Mean heart rates for mule deer bedding, standing, foraging and other active behaviors also increased in spring post- treatments. There were not enough observations during late summer to analyze pre- and post- period mountain sheep behaviors.

Video data collected during summer overflights were compared to data recorded from direct observations of animals. Individual variation was so great between individuals that video and direct observation data differed ($P < 0.05$) except when the same individuals were being recorded at the same time. Percent of time and mean duration of activities recorded during summer with

Table 2. Mean Heart Rates (Beats/Min) for Mountain Sheep for Pre- and Post-Baseline Maintenance Behaviors by Season, University of Arizona, Tucson, 1990-1991.

	Walk		Bed		Stand		Run		Forage		Active		Inactive	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Summer[a]														
$\bar{X}$	71.18	73.12	52.63	52.72	60.23	63.05	108.73	116.25	61.00	62.96	66.61	70.59	52.63	52.77
SE	1.65	0.91	0.37	0.34	0.43	0.56	3.61	6.77	0.56	0.63	0.93	0.97	0.37	0.34
Range	44-116	52-116	32-76	40-112	40-88	48-112	60-142	76-136	40-96	48-100	40-136	48-152	32-112	32-84
No. sheep	4	4	4	4	4	4	3	3	4	4	4	4	4	4
No. obs.	190	147	826	378	492	302	22	16	240	154	464	311	826	378
Late summer														
$\bar{X}$	84.40		68.44		71.65				72.62		73.25		68.45	
SE	5.92		1.04		1.22				1.85		1.71		1.04	
Range	56-104		40-100		52-112				60-92		52-112		40-100	
No. sheep	3		3		3				2		3		3	
No. obs.	10		161		80				26		64		161	
Spring														
$\bar{X}$	68.72	84.00	48.92	61.98	57.15	69.63	88.67	88.00	56.73	74.26	60.35	67.39	48.93	61.98
SE	1.91	0	0.49	1.34	0.67	2.33	12.67	0	1.28	3.67	0.95	2.85	0.49	1.34
Range	44-104	84	32-84	40-92	32-124	48-108	64-128	88	40-200	48-108	32-128	48-104	32-84	40-92
No. sheep	4	1	4	3	4	3	2	1	4	3	4	4	4	4
No. obs.	61	1	380	113	368	54	6	1	137	23	298	33	380	113

[a] Summer = 12 May-9 Aug 1990, Late summer = 13 Aug-12 Oct 1990, Spring = 4 Feb-5 Apr 1991.

Table 3. Mean Heart Rates (Beats/Min) for Desert Mule Deer for Pre- and Post-Baseline Maintenance Behaviors by Season, University of Arizona, Tucson, 1990-1991.

	Walk		Bed		Stand		Run		Forage		Active		Inactive	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Summer[a]														
$\bar{X}$	63.37	61.09	44.12	48.35	54.62	57.82	92.00	81.33	55.19	58.28	55.77	59.67	44.12	48.35
SE	2.49	1.35	0.49	0.35	0.66	0.59		10.05	0.74	0.89	1.10	1.03	0.49	0.35
Range	52-104	52-80	32-112	32-84	32-84	44-84	92	56-124	32-84	48-84	32-104	44-124	32-112	32-84
No. sheep	4	4	4	4	4	4	3	3	4	4	4	4	4	4
No. obs.	19	22	659	367	215	141	1	6	113	72	122	97	659	367
Late summer														
$\bar{X}$	67.11		54.54	53.78	61.68	69.50			60.46	69.11	64.35	70.67	54.54	53.78
SE	2.08		0.46	0.71	0.95	2.38			1.02	3.12	1.40	2.23	0.46	0.71
Range	48-80		40-80	40-68	40-104	56-96			44-80	56-96	40-104	64-76	40-80	40-68
No. sheep	3		3	3	3	3			2	2	3	3	3	3
No. obs.	18		277	83	119	24			69	18	68	6	277	83
Spring														
$\bar{X}$	62.18	73.09	46.32	52.52	56.63	62.99	92.00		55.08	61.77	59.40	66.22	46.32	52.52
SE	2.47	4.52	0.38	0.76	0.99	1.23	22.27		1.24	1.83	1.33	1.62	0.38	0.76
Range	40-108	56-100	32-68	36-72	32-128	40-100	64-136		36-116	44-100	32-136	40-100	32-68	36-72
No. sheep	4	1	4	3	4	3	2		4	3	4	4	4	4
No. obs.	55	11	365	115	349	95	3		166	52	241	54	365	115

[a] Summer = 12 May-9 Aug 1990, Late summer = 13 Aug-12 Oct 1990, Spring = 4 Feb-5 Apr 1991.

Table 4. Student's $\underline{t}$-test ($\underline{t}$) and Mann-Whitney (MW) $\underline{P}$ Values for Mean Pre- and Post-Baseline Heart Rates for Maintenance Behaviors of Mountain Sheep and Desert Mule Deer by Season, University of Arizona, Tucson, 1990-1991.

Season and species	Behavior									
	Walk		Bed	Stand	Run	Forage		Active		Inactive
	$\underline{t}$	MW	$\underline{t}$	$\underline{t}$	MW	$\underline{t}$	MW	$\underline{t}$	MW	$\underline{t}$
Summer[a]										
Sheep	0.306		0.784	0.001	0.212	0.023	0.003		0.784	
Deer	0.409		<0.001	<0.001	0.377	0.009		0.012		<0.001
Late summer										
Deer			0.414	0.005			0.011		0.073	0.414
Spring										
Sheep		0.235	<0.001	<0.001	0.256		<0.001	0.019	<0.001	
Deer		0.069	<0.001	<0.001		0.007		0.001	<0.001	

[a] Summer = 12 May-9 Aug 1990, Late summer = 13 Aug-12 Oct 1990, Spring = 4 Feb-5 Apr 1991.

video monitoring were the same ($\underline{P} < 0.05$) as recorded directly in summer when the animals and times compared overlapped.

Mountain sheep were observed walking more in the summer post- treatment than summer pre- treatment ($\underline{P} < 0.001$) and were observed bedding more in the spring post- treatment than spring pre- treatment ($\underline{P} < 0.001$). Deer were observed bedding more often in summer post- treatment than in summer pre- treatment ($\underline{P} < 0.001$) (Table 5).

There was no consistent trend in percent walking, bedding, standing, running, foraging, other active, or inactive behaviors across seasons between pre- and post- treatment periods. Mountain sheep were more active during post- summer and less active during post- spring. Desert mule deer bedded less during post- summer but behaviors did not differ between treatments for late summer or spring.

We examined duration of behaviors during treatments to see if rate of change between behaviors increased even if percent of time in each behavior did not. Individual variation was significant ($\underline{P} < 0.05$) confounding effects in all seasons. However, mountain sheep walked for shorter periods as summer progressed ($\underline{P} < 0.05$) (e.g., first 1 flight/day treatment > 7 flights/day > second 1 flight/day during summer). Mule deer walked for longer times during 7 flights/day treatments in late summer and spring. Mountain sheep foraged for longer times in spring than late summer ($\underline{P} = 0.0027$) and mule deer walked for longer times and bedded for shorter times in spring than summer and late summer ($\underline{P} < 0.05$). Duration of other behaviors did not differ significantly ($\underline{P} > 0.05$) between treatments within a season (Table 6).

Ambient temperatures during summer ($\bar{X} = 32.01^{\circ}$ C ± 0.18 [SE], range = 12-45), late summer ($\bar{X} = 29.46^{\circ}$ C ± 0.15, range = 20-40),

Table 5. Percent of Observations for Mountain Sheep and Desert Mule Deer Maintenance Behaviors During Pre- and Post-Baseline Periods, University of Arizona, Tucson, 1990-1991.

Season[a]	Animal	Behavior	Pre % time	Post % time	$\bar{X}$	P
Summer	Sheep	Walk	8.0	19.6	54.37	<0.001
		Bed	56.7	47.1		
		Stand	33.7	31.6		
		Run	1.6	1.4		
		Forage	15.7	17.6	15.14	<0.001
		Active	30.0	35.6		
		Inactive	54.4	46.9		
Summer	Deer	Walk	2.2	2.1	64.35	<0.001
		Bed	66.9	81.4		
		Stand	30.7	15.7		
		Run	0.1	0.8		
		Forage	12.6	13.2	4.03	0.133
		Active	14.5	17.1		
		Inactive	72.9	69.7		
Late summer	Sheep	Walk	4.7	8.3	7.59	0.055
		Bed	62.9	63.2		
		Stand	32.1	27.1		
		Run	0.3	1.4		
		Forage	10.3	8.3	1.05	0.59
		Active	26.7	26.0		
		Inactive	63.1	65.6		

Table 5. cont.

Season[a]	Animal	Behavior	Pre % time	Post % time	$\bar{X}$	P
Late Summer	Deer	Walk	2.8	1.6	1.22	0.749
		Bed	72.3	72.9		
		Stand	24.8	25.5		
		Run	0.1	0.0		
		Forage	14.9	14.7	7.44	0.24
		Active	12.8	7.6		
		Inactive	72.3	77.7		
Spring	Sheep	Walk	7.4	0.6	28.28	<0.001
		Bed	46.4	66.9		
		Stand	44.9	32.0		
		Run	1.2	0.6		
		Forage	16.7	13.6	25.03	<0.001
		Active	36.9	19.5		
		Inactive	46.4	66.9		
Spring	Deer	Walk	7.0	4.9	4.76	0.190
		Bed	45.6	52.7		
		Stand	46.9	42.4		
		Run	0.4	0.0		
		Forage	21.5	23.2	4.24	0.120
		Active	31.2	24.1		
		Inactive	47.3	52.7		

[a] Summer = 12 May-9 Aug 1990, late summer = 13 Aug-12 Oct 1990, spring = 4 Feb-5 Apr 1991.

Table 6. Mean Duration (Seconds) of Behaviors Recorded for Mountain Sheep and Desert Mule Deer During Overflight Treatment Periods at the University of Arizona, Tucson, 1990-1991.

Behavior class	Mountain sheep			Mule deer		
	$\bar{X}$	SE	N	$\bar{X}$	SE	N
Summer						
Walk	32.22	2.44	337	26.64A[b]	3.15	157
Bed	999.97	198.95	87	1761.51B	373.51	49
Stand	102.05	30.45	360	91.56	7.31	199
Run	11.35	1.42	63	21.71	4.04	14
Forage	130.98	17.01	50	132.05	14.54	55
Active	58.82	15.48	710	49.03	4.26	315
Inactive	999.97	198.95	87	1761.51C	373.51	49
Late summer						
Walk	30.89	4.63	2.83	22.94	4.27	89
Bed	731.01	69.40	68	1183.78D	69.55	78
Stand	62.29	5.76	306	125.81	16.46	110
Run	11.79	2.08	14			
Forage	80.62E	10.40	68	208.97	36.44	33
Active	42.03	3.92	535	54.13	8.21	166
Inactive	731.01	69.40	68	1183.78F	69.55	78

Table 6. cont.

Behavior class	Mountain sheep			Mule deer		
	$\bar{X}$	SE	N	$\bar{X}$	SE	N
Spring						
Walk	33.69	7.46	106	48.40A	8.15	131
Bed	729.70	82.73	46	905.59BD	117.38	29
Stand	107.70	11.54	148	135.42	13.03	148
Run	42.65	34.87	17	2.00		1
Forage	236.05E	45.06	22	202.98	30.06	45
Active	60.06	6.53	249	73.41	7.31	235
Inactive	729.70	82.73	46	905.59CF	117.38	29

[a] Summer = 12 May-9 Aug 1990, Late summer = 13 Aug-12 Oct 1990, Spring = 4 Feb-5 Apr 1991.

[b] Values in columns with the same uppercase letters differ significantly ($P < 0.05$).

and spring ($\bar{X}$ = 17.64° C ± 0.17, range = 3-28) may have contributed to behavior patterns. Overall, the animals engaged in less active behaviors during late summer than in other seasons. Although the mean ambient temperature was lower in late summer than in summer, the range of temperatures was greater possibly influencing activity levels.

Examination of heart rate responses during the treatment periods showed heart rates returned to the resting rates exhibited before the simulation events within ≤2.0 minutes (Fig. 2). Analyses with repeated measures ANOVA showed significant differences between individual animals. In summer, data came from 5 animals whose heart rate transmitters worked through the season. Measures for hr2, hr4, and hr5 differed between animals (F = 2.82, 4.02, 3.70; 3,62 df; P = 0.0463, 0.0112, and 0.0162, respectively). Late summer problems with heart rate transmitter failures provided sufficient observations for only 1 animal (mule deer no. 004). Therefore, differences between individuals could not be tested. In spring, data were sufficient for 8 animals. Individual differences were significant (F = 5.99, 3.10, 6.31; 6,12 df; P = 0.0043, 0.0445, 0.0034) for hr3, hr4, and hr5, respectively.

Wilk's lambda's (L); multivariate tests of interaction effects between time, animal, flight, and area, helped isolate the sources of variation in heart rates. For summer, time, time X flight, and time X area effects were significant (L) = 0.66; 4 df, 59; P < 0.0001; L = 0.52; 24 df, 207; P = 0.0199; and L = 0.71; 12 df, 156; P = 0.0496, respectively). Interactions including animal effects were not significant (P > 0.05). In other words, the rate of change between heart rate measurements was the same for all animals. However, the type of simulation event (flight) and the area in the pen did affect animals' heart rates. Significant flight effects (P ≤ 0.05) were apparent only in hr2 measures (e.g., right at the overflight). Animals

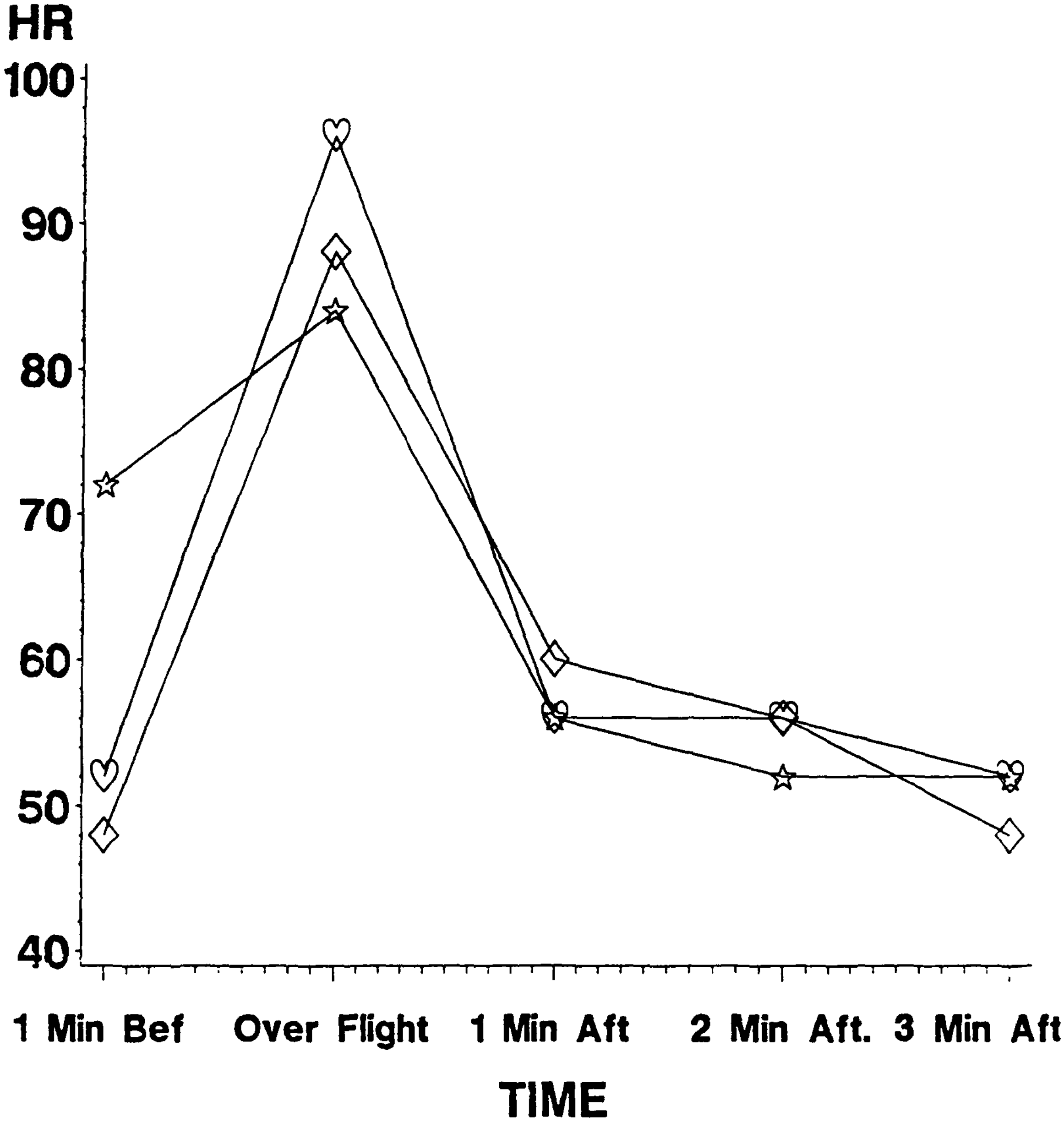

Figure 2. Heart Rate (HR) of an Adult Mountain Sheep 1 Minute (Min) Before (Bef), During, and 1, 2, and 3 Min After (Aft) a Simulated Overflight of an F-4D Aircraft (98.8 - 106.8/dB). This Experiment was Conducted During the Summer (12 May - 9 Aug) Period in Tucson, Arizona. The Sheep was Exposed to These 3 Overflights (First Exposure = Diamonds, Second Exposure = Hearts, Third Exposure = Stars) During Diurnal Hours and Each Flight was Separated from the Others by >1 Hour.

responded more to the higher sound level created by F-4D flights(Appendix B, tables 2,3,6,7,8) than to B1-B flights. Area effects were significant ($\underline{P} \leq 0.05$) from hr2 through hr5 with consistently greater response in area 2 (84.5-108.2 dB) than from areas 4 (76.5-100.2 dB) and 5 (72.5-96.2 dB).

Data for late summer was based only on 1 deer and only in zones 4 and 5. There were no significant responses ($\underline{P} \geq 0.05$) to differences in times, flights, or areas.

In spring only the time X area and time X animal X flight effects were responsible for the variation ($\underline{L} = 0.05$; 8 df, 18; $\underline{P} = 0.0002$, and $\underline{L} = 0.002$; 60 df, 37; $\underline{P} = 0.005$, respectively). Heart rate responses were greater from areas 2 (84.5-108.2 dB) and 3 (80.5-104.2 dB) than area 4 (76.5-100.2 dB). The 3-way interaction confounds animal and flight effects. However, significant heart rate differences ($\underline{P} < 0.05$) were most often greater with animals 004, 005, 012, and 014, and less for the noise created by the B1-B flying at 317 m (Table 1). The responses to this aircraft were consistently less than all but flights of the F-4D at 33 and 465 m. Animals 005, 012, and 014 were naive and added to the experiment for spring.

Mean response times for mountain sheep and desert mule deer were categorized into 2 types: time to return to original behavior, and time to return to maintenance behavior. Original behaviors were defined as an animal returning to the behavior(s) it was engaged in prior to the simulation event. Maintenance behaviors were defined as an animal returning to a common behavior (e.g., walking, bedding, standing, running, foraging) after a simulation event, not necessarily the behavior the animal was engaged in prior to the simulation event.

Mean alerted response times for mountain sheep (Table 7) indicate a decreasing response time with repetition; each succeeding

Table 7. Number of Alerted Responses and Mean Response Times to Simulated Aircraft Noise by Mountain Sheep and Desert Mule Deer, University of Arizona, Tucson, 1990-1991.

		$\bar{X}$ alerted response time[b] to return to original behavior[c] (sec)		
Season[a]	Animal	*n*	$\bar{X}$	*SE*
Summer	Sheep	11	43.8	27.0
	Deer	34	32.9	5.7
Late summer	Sheep	14	26.3	11.4
	Deer	12	33.2	9.3
Spring	Sheep	7	15.3	9.4
	Deer	12	33.2	9.3

[a] Summer = 12 May-9 Aug 1990, Late summer = 13 Aug-12 Oct 1990, Spring = 4 Feb-5 Apr 1991.

[b] Alerted response = animals exhibited alerted behavior, acknowledged location of stimuli, but did not alter their activity.

[c] Original behavior = animal returned to behavior engaged in prior to treatment.

season produced a decrease in alerted response time. This trend suggested habituation to the simulation events. Desert mule deer (no. 004) mean times for alerted responses decreased in late summer from summer. Animals added to the study after late summer (no. 005, 006, 012, and 014) were not exposed to previous simulation events, and may have reacted more intensely to the overflights, thus causing other animals to increase response times. For instance, animals that had been in the study the first 2 seasons may have responded more to a new animal's response, than to the actual overflight.

Mean alarmed response times for mountain sheep and desert mule deer (Table 8) duplicated the trend found in alerted responses of deer; mean response times decreased in late summer from summer, then increased in spring. Again, new animals added to the study may have contributed to these increases.

Table 8. Number of Alarmed Responses and Mean Response Times to Simulated Aircraft Noise by Mountain Sheep and Desert Mule Deer, University of Arizona, Tucson, 1990-1991.

		$\bar{X}$ alarmed response time[b] to return to original behavior[c] (sec)			$\bar{X}$ alarmed response time to return to maintenance behavior[d] (sec)		
Season[a]	Animal	n	$\bar{X}$	SE	n	$\bar{X}$	SE
Summer	Sheep	33	240.8	42.9	33	55.9	8.6
	Deer	10	114.5	55.2	10	51.8	16.9
Late summer	sheep	8	238.2	102.9	8	28.3	11.1
	Deer	6	21.6	9.3	6	21.6	9.3
Spring	Sheep	7	236.0	82.1	7	46.8	14.3
	Deer	6	252.3	131.1	6	78.2	28.1

[a] Summer = 12 May-9 Aug 1990, Late summer = 13 Aug-12 Oct 1990, Spring = 4 Feb-5 Apr 1991.

[b] Alarmed response = animals exhibited startle/alarm behavior, looked toward the speaker, ears directed toward the speaker, and altered their activity.

[c] Original behavior = animal returned to behavior engaged in prior to treatment.

[d] Maintenance behavior = animal returned to maintenance behavior after treatment (walking, bedded, standing, running, foraging).

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5. DISCUSSION

Heart rates increase in animals when they become excited or alarmed (Jacobsen 1981). Our data followed this trend. MacArthur et al. (1979) described mountain sheep resting and walking heart rates as 43.3-62.5 and 77.0-92.1 beats/minute (bpm), respectively. This is consistent with Harlow et al. (1987), Coates et al. (1990) and the mean heart rates for mountain sheep bedded and walking in this study.

Nearly all animals' heart rates returned to the resting heart rates recorded before the simulation events in $\leq$ 2.0 minutes. This is consistent with data from MacArthur et al. (1979) and Espmark and Langvatn (1985). Although repetition of stimuli commonly leads to habituation (Harris 1943), vulnerable animals should habituate reluctantly to stimuli that would indicate a possible threat (e.g., predators) (MacArthur et al. 1979, Espmark and Langvatn 1985).

We have no information on the long term effects (e.g., productivity and recruitment) of low-altitude aircraft noise on mountain sheep and desert mule deer. Jorgenson (1988) documented range abandonment of mountain sheep (*O. c. canadensis*) in Canada as a result of disturbance (e.g., human activities, helicopter flights) from the 1988 winter Olympics. Dorrance et al. (1975) noted that white-tailed deer (*Odocoileus virginianus*) altered their winter ranges in response to human activities. Disturbances such as these could cause detrimental changes in energy budgets. However, Harrington and Veitch (1991) reported the greatest impact of low-level flying jet aircraft on caribou will be due to the startle reactions caused by the loud and sudden noise of low, direct overflights. They did not demonstrate detrimental changes to energy budgets.

Wildlife and domestic species can habituate to human-related disturbances (Dorrance et al. 1975, MacArthur et al. 1979,

Espmark and Langvatn 1985, Yarmoloy et al. 1988) over time. Fletcher (1988) noted that various studies on the effects of low-altitude jet and helicopter overflights on domestic animals in Germany, identify physiological changes that indicate aircraft noise exposure may influence animals. Cautious control of the stimulus is necessary for studies testing wildlife responses to aircraft noise (Brown 1990). Our experiment has confirmed that simulation events can render a means by which accurate and replicable aircraft noise can be exposed to wildlife species. Our data illustrates that short term habituation to noise from aircraft does occur over time.

The observational methods used in this study demonstrate that many behavioral responses of mountain sheep and desert mule deer to jet aircraft noise are subtle and differ with experience, age, and season (Jacobsen and Stuart 1978, Moen 1978, Kreeger et al. 1989). A trend toward habituation was exhibited by mountain sheep and desert mule deer. When younger and naive animals replaced older animals after late summer, the mean heart rates and response times reflected these changes accordingly. Seasonal variation in heart rates were pronounced in this study and can reasonably be predicted (Holter et al. 1976, Moen 1978, Nilssen et al. 1984, Geist et al. 1985). Daily fluctuations in heart rates could reflect endogenous rhythms or metabolic responses to changing ambient temperatures (Palmer 1976, Stemp 1983). Because the design of this study was to monitor animals by season, daily heart rate fluctuations were not calculated. In addition, physiological measurements are affected by previous activity (Geist et al. 1985), something not included in our analyses.

Animals strive to live in predictable, secure environments at the lowest maintenance costs (Geist et al. 1985). Free-ranging mountain sheep have demonstrated that they will habituate to repeated disturbances and most cardiac responses are short-lived (MacArthur et al. 1982, Geist et al. 1985). Elk (Morgantini and

Hudson 1979, Ward and Cupal 1979, Kuck et al. 1985), mountain sheep (Geist et al. 1985), mule deer (Krausman et al. 1986), caribou (Harrington and Veitch 1991), and white-tailed deer (*Odocoileus virginianus*) (Dorrance et al. 1975) respond more severely to direct, unpredicted human harassment than to mining, helicopters, or other disturbances. Geist (1978) noted that, although mountain sheep can be easily habituated to human contact over time provided there is no hunting, mountain goats (*Oreamnos americanus*) tend to remain timid and are much less readily approached. Exposure to prolonged, frequent, and unpredictable human disturbance could severely affect species behavior, with implications to physiology, population dynamics, and ecology (Geist 1971).

The same effects may be attributed to aircraft noise. Furthermore, there may be additional, or interactive effects from the visual stimulus of aircraft (Brown 1990, Harrington and Veitch 1991). Upon perceiving a signal indicating possible danger, for instance when pain or novelty are involved, an animal's first response is to turn its attention to the source of the signal (Brown 1990), such as the speaker in this study. This process is known as the orienting response (OR) or orienting reflex (Archer 1979, Brown 1990). Generally the OR is elicited by high intensity, novel or unpredictable stimuli. It entails the sense organs being oriented by physiological changes indicating increased readiness to respond (e.g., increased heart rate). The OR becomes progressively less severe with repetition of stimuli (Archer 1979). For instance, the alerted response by mountain sheep or desert mule deer in this study entailed the animal looking toward the speaker, or ears directed toward the speaker during a given simulation event, while possibly remaining bedded.

If an unexpected stimulus is of a particularly high intensity, the initial OR may be replaced by a defense mechanism (e.g.,

blinking and crouching) to aid in protection from possible noxious stimuli (Archer 1979). During the time between the stimuli and the response, there is little time for the animal's nervous system to analyze the situation.

A simple and successful way of observing the environment for potential threats involves reacting quickly to any unusual stimuli (Archer 1979). For instance, the mean increase in response times and heart rates during spring may be indicative of this process. Experienced animals may have responded more to a startled animal than to the actual simulation event. Following the initial response, the stimulus can be analyzed further and possibly accompanied with 1 of several other defense mechanisms. The behavior of animals in this study exposed to low-altitude aircraft noise (92.5 - 112.2 dB) was not uniform. Individual variation in behavior was significant ($\underline{P} < 0.05$) and confounded effects in all seasons. However, their heart rates increased with increased dB levels but the rate of increase decreased with repetition. These data suggest habituation to the simulation events. The data from this study can be used to develop future management plans and better understanding how animals respond, both physiologically and behaviorally, to low-altitude military aircraft.

APPENDIX A

DEFINITIONS

"A" weighted sound[a]: a standardized measure that assigns low weights to low-frequency sounds, that the human ear is less sensitive to, and higher weights to the more audible (for humans) high-frequency sounds. Sound pressure level in decibels measured by use of the A, B, or C frequency weighting;and fast, slow, or impulse exponential time averaging or peak time-related charactic.

Background noise[a]: the total noise from all sources in a system that interferes with the production, detection, measurement or recording of a signal.

Chronic stress: long-term change in physiological or behavioral patterns resulting from response to insult.

Decibel (dB)[a]: logarithmic scale of sound pressure.

Frequency[a]: the number of sound waves per second produced by a sounding body. Pure tone sound (e.g., a tuning fork) consists of a single frequency. However, most sounds extend over a wide range of frequencies, with different amplitudes at different parts of the range.

L_{eq}[a]: time average sound pressure level; for airborne sound the l_{eq} in dB is 20 times the logarithm to the base 10 of the sound pressure level during the stated time to the reference sound pressure of 20 μ pascal unit:dB.

L_{max}: maximum A-weighted sound level in exposure zone produced by overflight simulation.

Low-altitude overflight: jet aircraft flying at < speed of sound between 61 and 465 m above the ground.

Maintenance behavior: the common behavior that an animal returned to following a simulation event (e.g., walking, bedding, standing, running, foraging). Not necessarily the behavior the animal was engaged in prior to the simulation event.

Noise[a]: any disagreeable or undesired sound or other disturbance.

Offset: horizontal distance between flight path and location of subject.

Onset: rate of increase of sound level, measured in dB/second.
Original behavior: behavior subject animal was engaged in before overflight simulation event.
Sonic boom: noise, pressure disturbance, caused by aircraft travelling faster than the local speed of sound.
Sound: a pressure fluctuation in an otherwise undisturbed atmosphere or other medium (e.g., ground or water).
Sound pressure[a]: a fluctuating pressure superimposed on the static pressure by the presence of sound. Its' magnitude can be expressed in several ways, such as instantaneous sound pressure, maximum sound pressure, or the square root of the mean-square sound pressure.
Stress: a body's nonspecific response to an insult.

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[a] These definitions are from the American National Standard on Acoustical and Electroacoustical Terminology. They are compatible with definitions contained in existing national and international standards (i.e., IEC publ. 50, Chapter 801:Acoustics and Electroacoustics; and ANSI/ASTM 634 - 79a: Standard Definitions and Terms Relating to Environmental Acoustics).

APPENDIX B
NOISE SIMULATION SYSTEM FOR LOW-LEVEL AIRCRAFT OVERFLIGHTS

Acentech Incorporated

Acoustical & Environmental Technologies

REPORT NO. 28
PROJECT NO. 609101

NOISE SIMULATION SYSTEM FOR LOW-LEVEL AIRCRAFT OVERFLIGHTS

USER'S MANUAL

PAUL CHAVEZ
B. ANDREW KUGLER
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RICHARD HOWE

SUBMITTED TO:

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A Bolt Beranek and Newman Company

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NOISE SIMULATION SYSTEM FOR LOW-LEVEL AIRCRAFT OVERFLIGHTS

1. Introduction

1.1 Overview

This manual presents a description of the Noise Simulation System (NSS). The NSS is designed to simulate the aircraft noise generated on low-level Military Training Routes (MTRs) by a variety of aircraft types. Table 1 shows the range of conditions covered in terms of the magnitude of the noise and onset time. The objective of the NSS is to provide the University of Arizona with a calibrated source of aircraft-generated noise in support of their study on bighorn sheep behavioral and physiological responses to low-level jet aircraft overflights.

1.2 Description of the Noise Simulation System

The NSS utilizes prerecorded noise samples of a variety of low-flying aircraft which are played back through a Panasonic Digital Audio Tape player (DAT). The aircraft noise events are generated via a loudspeaker cluster projected above the animals to simulate the flyover conditions. The penned observation area around the loudspeaker has been calibrated into areas of known sound levels. Thus, for each aircraft type, speed, and altitude, the noise level magnitude and range over a designated ground area are known. The observer studying the reactions of the test animals needs to record only the location of the subject at the time of the event and the aircraft sample number to identify the noise exposure received.

2. Use of the Noise Simulation System

2.1 System Design

Figure 1 shows a flow chart of the NSS. The key elements of the system are the Digital Audio Tape player used to reproduce the tape-recorded samples and the Amplifier/Speaker combination used to output these samples at high intensity levels to simulate the low-level overflights. The layout of the equipment rack is shown in Figure 2.

2.2 Using the Noise Simulation System

The system has been designed for easy use. A few general rules for efficient and safe use are as follows:

1) Never turn the power to the system off without first ejecting the DAT tape from the tape player;

2) Always turn the power to the rack off by using the switch at the top of the rack; and

3) Do not plug in or unplug the rack when this switch is ON.

4) Do not adjust any equipment settings except for volume control for cue track on the powered monitor and the playback controls on the DAT player (see Figure 2).

The toggle switch in the top section of the rack (the Power Conditioner Section as shown in Figure 2) controls the power to the entire system. After ensuring that the rack is plugged in, simply flip this switch to ON. For best results, let the system warm up for approximately 15-25 minutes. You will then be ready to play the low-flyover sample over the NSS.

To turn the system off, eject the DAT tape by pressing the OPEN/CLOSE button (see 3, Figure 3a). Then flip the power switch to OFF on the Power Conditioner. This will turn off the entire system.

2.3 Playing Back Low-level Aircraft Overflight Noise Data

Once the system is turned on, the tape must be placed in the DAT player (see Figure 2). To do this, press the OPEN/CLOSE button on the DAT (see 3, Figure 3a). This will open the cassette compartment. Carefully place the tape in the compartment. Press the OPEN/CLOSE BUTTON on the DAT player again to close the compartment.

Choose the flyover event and its corresponding ID number from Table 1, as needed (refer to Section 3.1). When you are prepared to play the signal, press the ID number on the Numeric Keypad (13, Figure 3b) and then press the PLAY button (33, Figure 3c). The DAT player will search for the sample and play it. You do not need to play samples sequentially. For example, you can play sample 8, then 2, and then 10.

The time it takes for the DAT to find the sample on the tape will vary. For example, if the tape is positioned at the beginning and you press "10 - PLAY," the tape will have to fast-forward to arrive at sample 10, an event which will have occurred several minutes into the tape, to begin. This entire process should take no more than 10-20 seconds.

After the sample has played and the event number has incremented to an odd number, **you must press STOP on the DAT player**. The odd ID numbers are 30-second buffer sections which will allow you time to stop the tape after the sample.

By using the powered monitor (see Figure 2), the user can also monitor the "cue track" on the right channel to monitor verbal descriptions of the signals and "STOP RECORD" warning messages, which notify the user to stop the system playback. The volume of the cue track may be adjusted with the knob to the right side of the powered monitor speaker.

It is possible to program a sequence of flyover events for long-term playback. This process is similar to selecting a particular track for playback. Simply enter the number of the first desired event from Table 1 on the Numeric Keypad and then press the MEMORY button. Enter the ID of the next event and press the MEMORY button again. Continue this until all desired events have been programmed. Then simply press the PLAY button and the events will be played back in the selected order. For more details on the programming process, refer to page 16 in the DAT users manual.

3. Use of Low-Level Overflights Aircraft Tapes

3.1 Flyover Sample Tape Contents

Table 1 is an explanation of the samples recorded on the tape supplied. As stated in the introduction, the samples cover the typical range of aircraft types, speeds and altitudes flown on MTRs. The explanations and definitions of the aircraft operational data presented in Table 1 are shown below.

ID # Number associating flyover description with number used to key into DAT player to begin playback.

A/C TYPE Aircraft Type.

ALT Altitude of aircraft when sample was recorded, in feet.

OFFSET The lateral distance between the recording station and the aircraft during overflight, in feet.

SPEED Airspeed of aircraft.

All of the noise data in Table 1 are presented in terms of either A-weighted or C-weighted sound levels. The definitions of the descriptors presented are given below.

LEQ Equivalent Sound Level. The LEQ is defined as the steady A-weighted sound level which produces the same A-weighted sound energy over a stated period of time as a specified time varying sound. In this case, the time period starts when the aircraft noise exceeds a level of 70 dB and ends when the level falls below 70 dB.

MAX Maximum rms dB level achieved during flyover.

SEL Sound Exposure Level. SEL is the level in decibels of the time integral, relative to one second of the sound level, usually over a single event.

3.2 Determining Noise Exposure Levels in Observation Area

Tables 2 through 17 summarize the values of the noise level descriptors for each aircraft sample in each of the subareas identified in Figure 4. Since the noise environment is not constant in each subarea, a noise level range is given in the last column. For exam e, Table 2 presents the values for sample ID number 4 of a B1-B flyover. The area designation 1 shows an Equivalent Noise Level (LEQ) of 90.5 dBA. The range of noise levels for this area is given as ±2.0 dB. This means that the LEQ level in Area 1 for this flyover sample is between 92.5 and 88.5 dBA with a mean value of 90.5 dBA.

The sizes of the subareas selected were based on practical considerations, such as being able to distinguish where the subject animal was at the time of the event. Note that the noise levels described in Table 1 are valid only in closest location of area 1 since at other points in the pen, noise generated by the loudspeaker will be attenuated as a function of distance and angle from the source. For specific dimensions of the subareas in the observation pen, see Section 4.1.

4. Maintenance

The rack-mounted electronics for this system should always be kept indoors where temperature is moderate. It should also be kept in a dry area, where there is no possibility of exposure to water or other liquids. Both covers should be off when the system is in use to facilitate airflow in the

rack, since some of this equipment needs to dissipate self-produced heat. The amplifier has an internal fan to assist in self-cooling.

4.1 Identification of Observation Areas

Figure 5 is a map of the observation area describing the layout and the location distances and angles which delineate the noise level subareas. The dimensions shown on this figure should be used to locate the lines dividing the space into subareas of constant noise characteristics.

Figure 4 shows the designation numbers for the color-coded noise areas identified. A practical and simple method should be used to make areas easily visible to the observer from the observation stations. Two techniques discussed with University of Arizona personnel were 1) mowing lines representing the area borders, and 2) placing longer, color-coded stakes that can easily be identified by outside observers.

4.2 Protecting System When Not In Use

When the user is aware that the system will not be in use for long periods of time, the components case lids should be kept on.

To cover the speaker cabinet, place the black lids over each speaker and latch them down. Then place the large, grey cover over the cabinet and fasten the latch. Locking the cabinet may also be desired. This will keep the speaker from exposure to moisture and fluctuations in temperature. When the weather reaches a temperature of or below -30°, it is advisable not to use the system. During prolonged periods of extreme low temperatures the speaker should be stored inside. See also Section 4.3 on removing/installing the speaker.

To cover the electronics, replace the front panel lid first to prevent damage to the panel. Unplug the AC cord from the outlet and carefully store it inside the cabinet. Then, after observing and marking the terminal into which it is plugged, unplug the speaker cable and store it in a safe place.

Replace the back cover just as you did the front cover. This will keep the electronics protected from dust.

When the speaker cable is plugged back in for use, it is very important to plug the connector into the correct terminal on the back of the amplifier. The speaker connectors are known as "banana plugs." The red banana plug must be plugged into the red CH1 terminal and the black banana plug must be plugged into the red CH2 terminal. <u>DO NOT PLUG THIS CONNECTOR INTO THE BLACK POSTS OR YOU MAY DAMAGE THE SPEAKER OR THE AMPLIFIER</u>. Note that this is contrary to the way in which a typical stereo amplifier is used, so that it can be used as a higher power mono amplifier instead of a stereo amplifier.

4.3 Removing/Installing the Speaker

If scaffolding is to be replaced, or if the speaker cabinet needs to be stored inside for bad weather months, the speaker must be taken down from its calibrated placement.

To safely lower the speaker, attach ropes to both sides of the speaker hanging hooks, and use the pulleys which are attached to the scaffolding to lower it. This will take at least four people to accomplish, since it will require two people to unlatch the speaker from the support chains and two people to lower the speaker with the ropes. If possible, leave the support chains on the scaffolding for simple reinstallation. If the support chains cannot be left, note the length of each chain so that you can replace it as it was before.

A diagram (Figure 6) has been included to facilitate the replacement of the speaker. The speaker must be positioned facing down at a 41.5° angle with the center of the speaker 20 ft from the ground, as shown in Figure 6. The angle can be verified with a small, liquid level which allows the user to set the angle desired. Place the level on the speaker and center it with the angle set to 41.5°. (A tool of this type was left with the system when it was installed.)

4.4 Checking the Calibration of the System

On the Flyover Sample Tape, there is a calibration signal on ID number 2. This calibration signal should register as 94 dBA, ±2 dBA, at the point of reference, which can be defined as on the 17 ft. line at 0° (see Figure 4), 5 ft above the ground. This can be checked with a Type 1 sound level meter. (Checking with a lower quality sound level meter may lead to erroneous measurement levels.) If after a long period of time or after the replacement of the speaker the calibration signal registration changes, contact Paul Chavez at Acentech Incorporated, at (818) 347-8360.

5. Manufacturers Equipment Manuals

This section includes all the available literature supplied with the equipment specific to the Noise Simulation System.

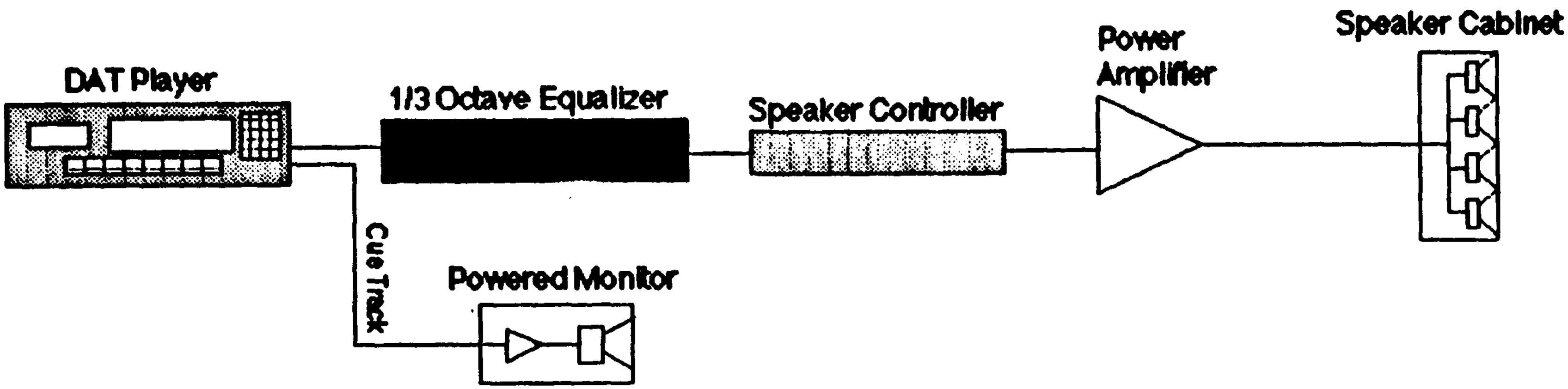


FIGURE 1. FLOW CHART OF NOISE SIMULATION SYSTEM

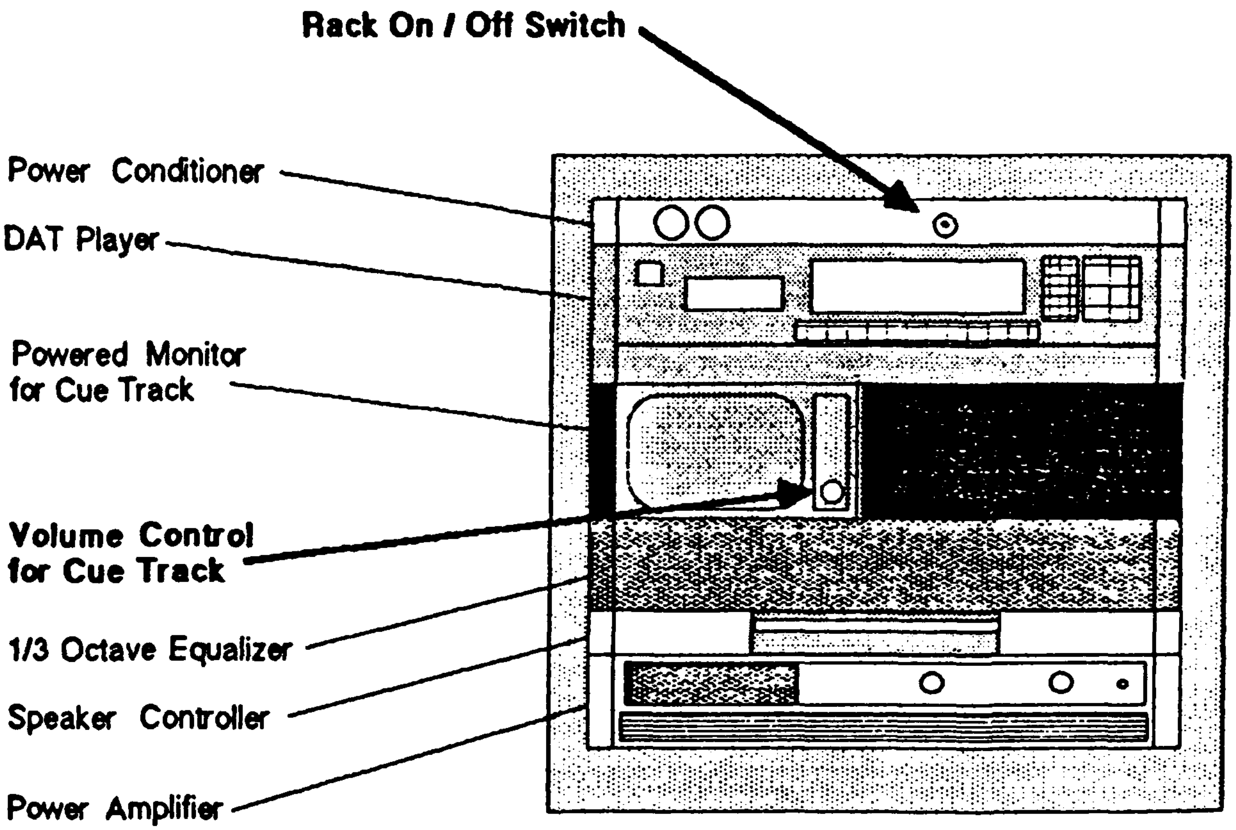
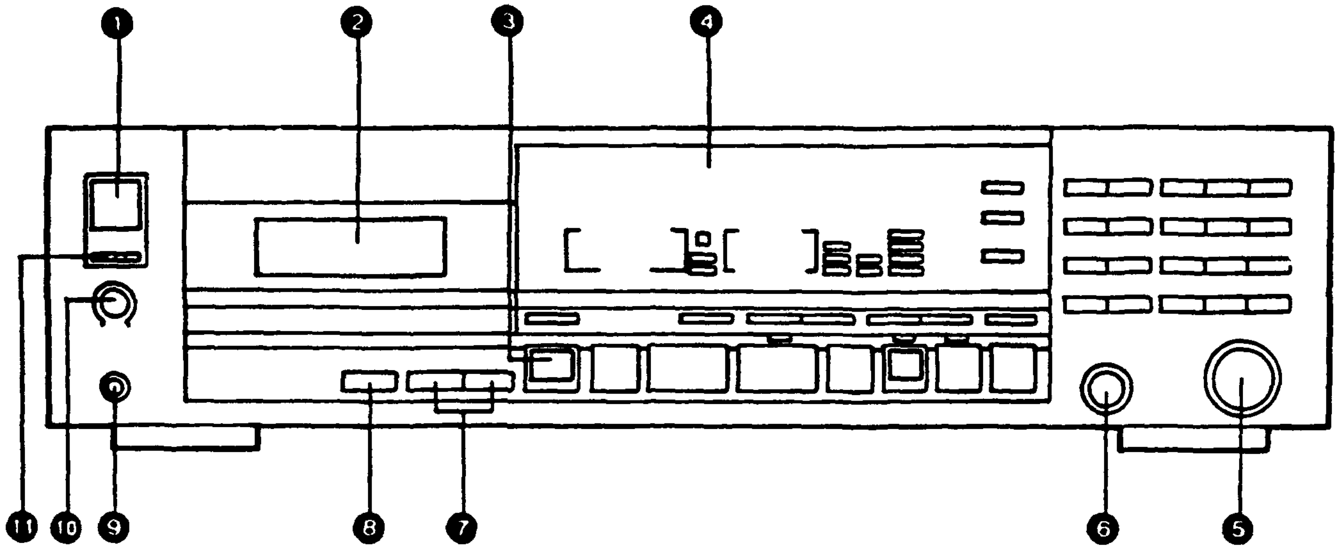


FIGURE 2. ELECTRONIC EQUIPMENT RACK LAYOUT



❶ **POWER switch**

❷ **cassette holder**

❸ **OPEN/CLOSE button (⏏)**

❹ **display**

❺ **REC LEVEL control**
Use to adjust the recording level.

❻ **REC BALANCE control**
Use to adjust recording balance between left and right

❼ **SKIP buttons (⏮ · ⏭)**
Use the skip buttons to advance to the desired program.
The ⏭ button skips the program forward
The ⏮ button skips the program backward

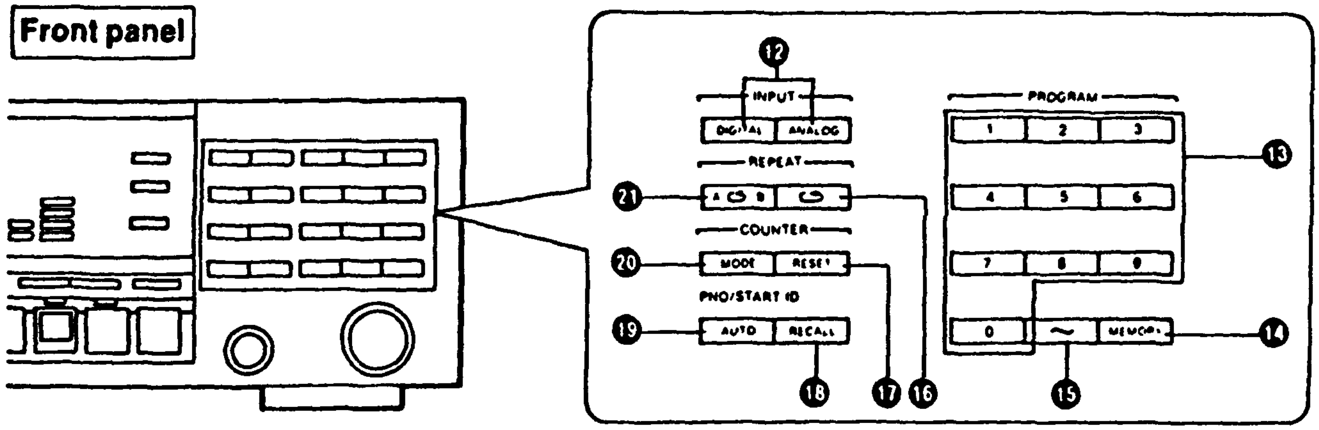
❽ **END SEARCH button**
Use to advance at high speed to the end of the recorded portion of the tape.
Use also to continue recording from the last recorded position, or to find the total number of programs or total time recorded on the tape (in the case of tapes where absolute time and program numbers have been recorded).

❾ **PHONES jack**
A ¼" connector for standard stereo headphones.

❿ **PHONES LEVEL control**
Use this control to adjust the output level to the headphones.

⓫ **TIMER selector**
Used to automatically begin playback or record when the unit is connected to an AC line timer. Setting this switch to "REC" or "PLAY" causes the unit to switch to record or playback mode as soon as AC power is applied.
If a timer is not used, leave this switch in the "OFF" position.

Figure 3a. Location and Function of Controls on DAT Player



12 INPUT selector button

Use to select digital or analog recording input.

13 PROGRAM buttons

Use to select program numbers, to cue to a desired track, etc.

14 MEMORY button

Use to program a random playback sequence.

15 continuous memory button (~)

This button is used to reduce program steps needed when consecutive programs are to be played during a random sequence (e.g. 2~5 instead of 2, 3, 4, 5).

16 REPEAT button (C⮌)

Use to repeat playback of a tape or a programed sequence.

17 COUNTER RESET button

Use to reset the tape counter to "0000" (when the display mode is set to tape counter).

18 RECALL button

Use to display and check program numbers which have been memorized.

19 AUTO button

Use to automatically record program numbers or start ID's during recording or indexing by detecting the beginning of signal after a blank position.

20 COUNTER MODE button

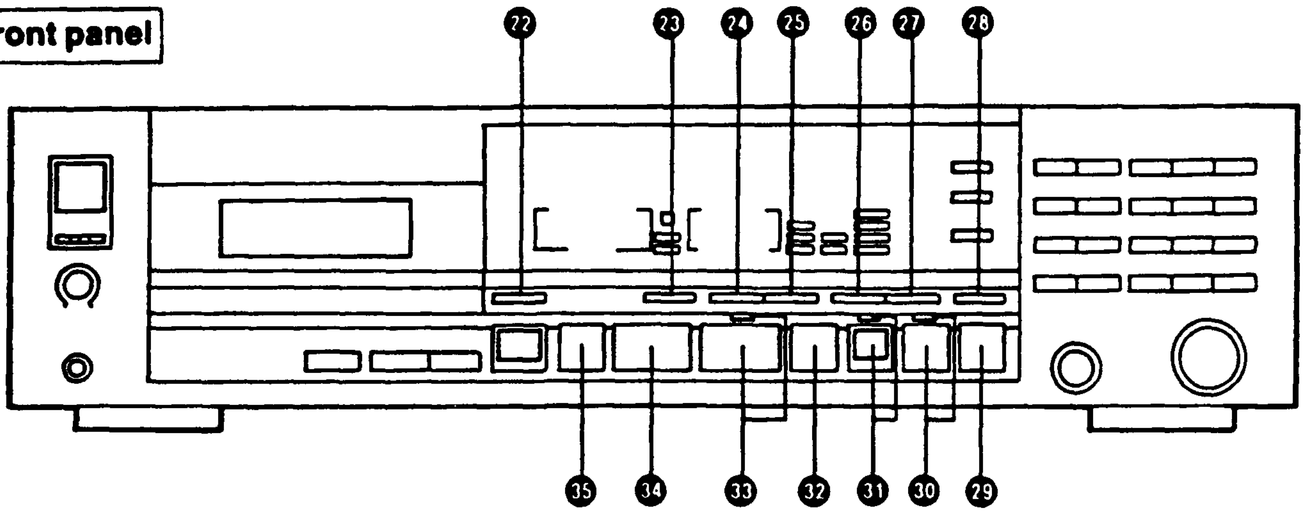
Use to select the desired counter mode.
(absolute time, program time, tape counter)

21 A-B REPEAT button (A C⮌ B)

Use to repeat a portion of the tape between A and B.

Figure 3b. Location and Function of Controls on DAT Player (Continued)

Front panel



22 MUSIC SCAN button
Use to play back the beginning of each recorded program on the tape for about 9 seconds.
This is useful for quick identification of program contents.

23 INDEX button
Indexing allows certain subcode data which has been recorded on the tape to be changed with no effect to the actual program recording.
With this unit, the following types of indexing are possible.
1. Recording or erasure of start ID's at the beginning of a program
2. Recording or erasure of skip ID's
3. Renumber function

24 START ID/WRITE button
Use to record start ID's in indexing. Can be done automatically or manually as desired.

25 SKIP ID/WRITE button
Use to record skip ID's in indexing.

26 START ID/ERASE button
Use to erase start ID's recorded in indexing.

27 SKIP ID/ERASE button
Use to erase skip ID's recorded in indexing.

28 RENUMBER button
Use to assign program numbers (01, 02, 03...) to start ID's recorded in indexing.

29 AUTO REC MUTE button (○)
Use to automatically insert a silent space approximately four seconds long during a recording.

30 PAUSE button/indicator (❚❚)
Use to temporarily interrupt playback or recording.

31 REC (record) button/indicator (●)
Use to put unit in record standby mode.

32 FF/CUE (fast forward/cue) button (▶▶)
Use to advance the tape rapidly or for audible high-speed search (cue).

33 PLAY button/indicator (▶)
Use to initiate recording or playback.
Use also to record program numbers manually.

34 STOP button (■)
Use to stop all functions.
This button also clears the program memory.

35 REW/REV button (◀◀)
Use to rewind the tape or for audible high-speed search (review).

Figure 3c. Location and Function of Controls on DAT Player (Continued)

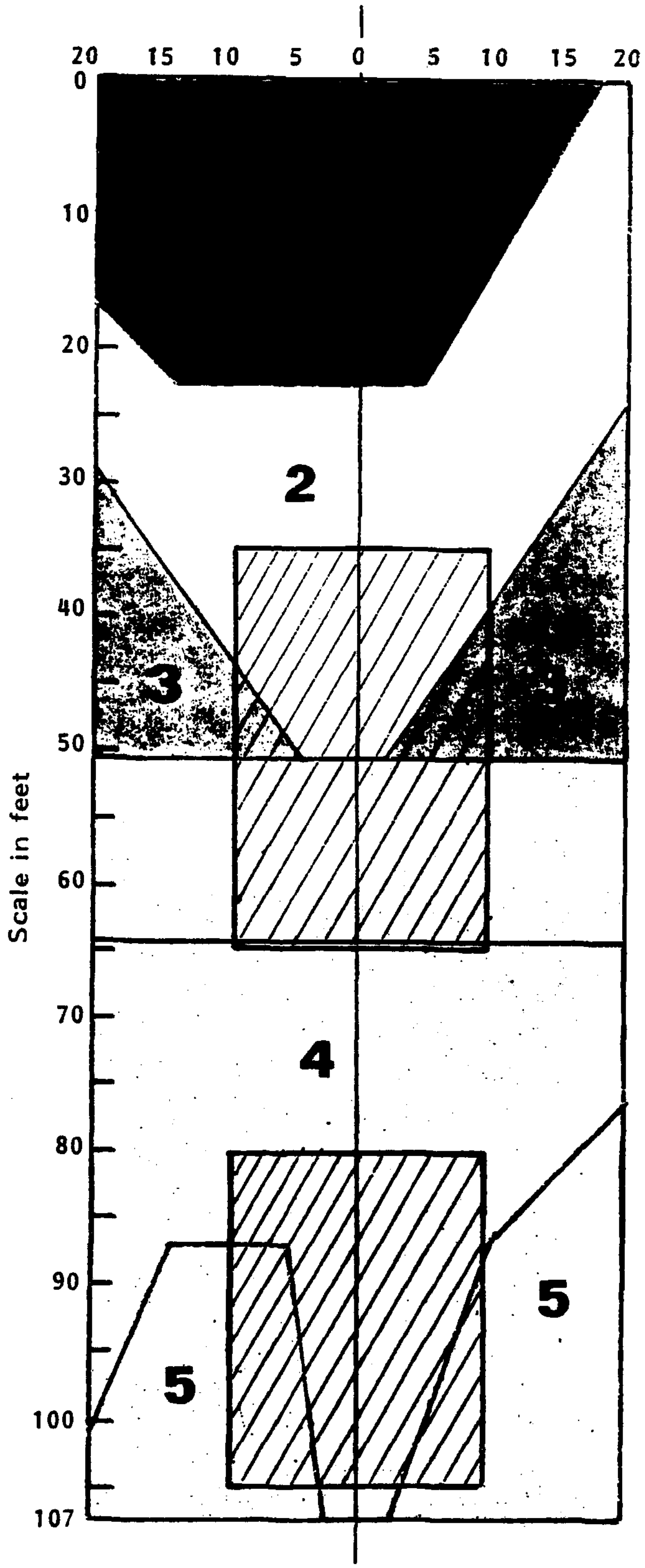


FIGURE 4. OBSERVATION AREA NOISE SUB-AREA MAP

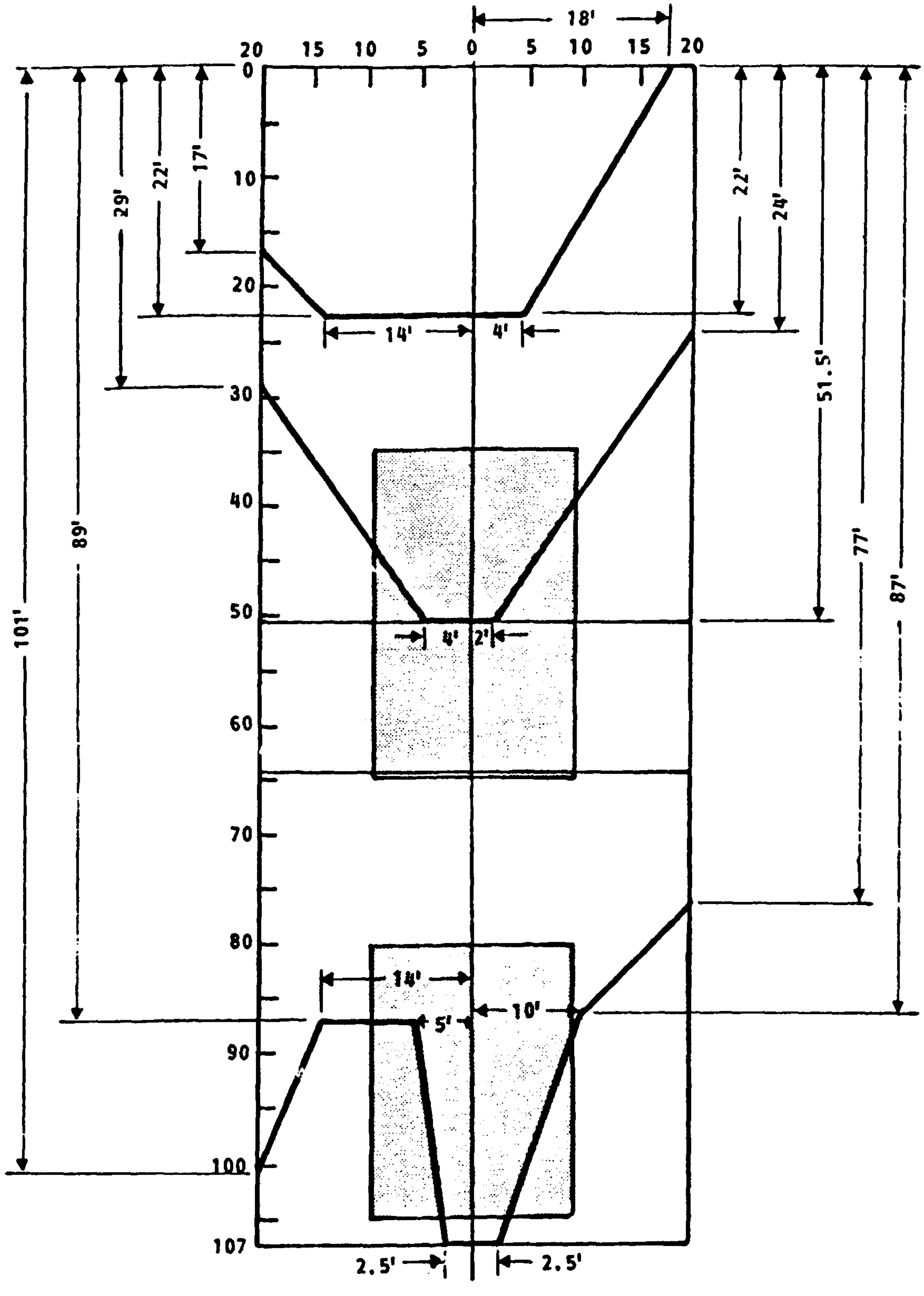


FIGURE 5. OBSERVATION AREA NOISE SUB-AREA MAP

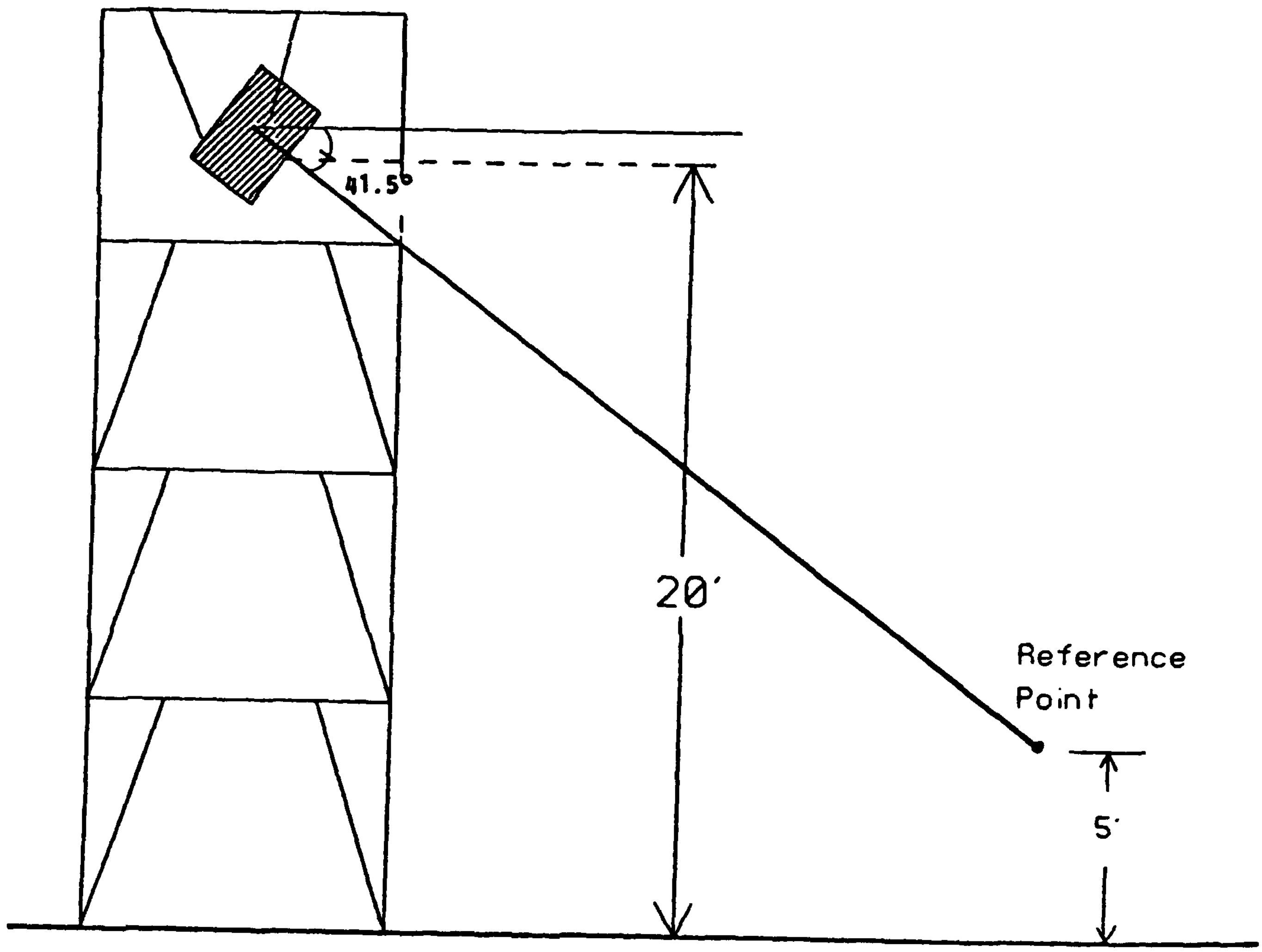


Figure 6. Speaker Placement Diagram

UNIVERSITY OF ARIZONA, BIGHORN SHEEP STUDY "DAT" TAPES

AIRCRAFT FLY-OVER SIGNAL						DAT TAPES (with LD 870) AIRCRAFT FLY-OVER NOISE DESCRIPTORS				
						"A" WEIGHTED			"C"WEIGHTED	
ID#	A/C TYPE	ALT (FT)	OFFSET (FT)	SPEED (KTS)	ONSET dB/SEC	LEQ	MAX	SEL	MAX	SEL
4	B-1B	1039	1023	578	10.7	92.5	101.0	103.2	102.7	105.9
6	B-1B	1035	19	578	17.9	96.3	108.1	107.9	109.6	110.5
8	B-1B	546	59	575	27.0	100.0	112.2	109.6	113.5	112.1
10	F-4D	108	2033	534	10.1	83.8	92.5	94.0	92.1	94.4
12	F-4D	1527	36	561	20.2	94.9	107.2	107.9	107.6	109.5
14	F-4D	781	31	586	33.8	99.5	109.3	109.3	109.6	110.6
16	F-4D	514	55	592	45.6	99.3	108.8	107.8	108.8	108.5
18	15 Minute Blank Space									
20	30 Minute Blank Space									
22	1 Hour Blank Space									

TABLE 1. SUMMARY OF TAPE CONTENTS INCLUDING SELECTED LOW-LEVEL AIRCRAFT FLYOVER SIGNALS

ID#:4 A/C Type:B-1B

Area	A-Weighted Noise Level Descriptors (dBA) LEQ	MAX	SEL	C-Weighted Noise Level Descriptors (dBC) MAX	SEL	Noise Level Range in Area (dB)
1	90.50	99.00	101.20	100.70	103.90	± 2.00
2	86.50	95.00	97.20	96.70	99.90	± 2.00
3	82.50	91.00	93.20	92.70	95.90	± 2.00
4	78.50	87.00	89.20	88.70	91.90	± 2.00
5	74.50	83.00	85.20	84.70	87.90	± 2.00

TABLE 2. SUMMARY OF NOISE LEVELS IN OBSERVATION PEN AREAS FOR AIRCRAFT SAMPLE NO. 4

ID#:6 A/C Type:B-1B

Area	A-Weighted Noise Level Descriptors (dBA) LEQ	MAX	SEL	C-Weighted Noise Level Descriptors (dBC) MAX	SEL	Noise Level Range in Area (dB)
1	94.30	106.10	105.90	107.60	108.50	± 2.00
2	90.30	102.10	101.90	103.60	104.50	± 2.00
3	86.30	98.10	97.90	99.60	100.50	± 2.00
4	82.30	94.10	93.90	95.60	96.50	± 2.00
5	78.30	90.10	89.90	91.60	92.50	± 2.00

TABLE 3. SUMMARY OF NOISE LEVELS IN OBSERVATION PEN AREAS FOR AIRCRAFT SAMPLE NO. 6

ID#:12 A/C Type:F-4D

Area	A-Weighted Noise Level Descriptors (dBA)			C-Weighted Noise Level Descriptors (dBC)		Noise Level Range in Area (dB)
	LEQ	MAX	SEL	MAX	SEL	
1	92.90	105.20	105.90	105.60	107.50	± 2.00
2	88.90	101.20	101.90	101.60	103.50	± 2.00
3	84.90	97.20	97.90	97.60	99.50	± 2.00
4	80.90	93.20	93.90	93.60	95.50	± 2.00
5	76.90	89.20	89.90	89.60	91.50	± 2.00

TABLE 6. SUMMARY OF NOISE LEVELS IN OBSERVATION PEN AREAS FOR AIRCRAFT SAMPLE NO. 12

ID#:14 A/C Type:F-4D

Area	A-Weighted Noise Level Descriptors (dBA)			C-Weighted Noise Level Descriptors (dBC)		Noise Level Range in Area (dB)
	LEQ	MAX	SEL	MAX	SEL	
1	97.50	107.30	107.30	107.60	108.60	± 2.00
2	93.50	103.30	103.30	103.60	104.60	± 2.00
3	89.50	99.30	99.30	99.60	100.60	± 2.00
4	85.50	95.30	95.30	95.60	96.60	± 2.00
5	81.50	91.30	91.30	91.60	92.60	± 2.00

TABLE 7. SUMMARY OF NOISE LEVELS IN OBSERVATION PEN AREAS FOR AIRCRAFT SAMPLE NO. 14

ID#:16 A/C Type:F-4D

Area	A-Weighted Noise Level Descriptors (dBA) LEQ	MAX	SEL	C-Weighted Noise Level Descriptors (dBC) MAX	SEL	Noise Level Range in Area (dB)
1	97.30	106.80	105.80	106.80	106.50	± 2.00
2	93.30	102.80	101.80	102.80	102.50	± 2.00
3	89.30	98.80	97.80	98.80	98.50	± 2.00
4	85.30	94.80	93.80	94.80	94.50	± 2.00
5	81.30	90.80	89.80	90.80	90.50	± 2.00

TABLE 8. SUMMARY OF NOISE LEVELS IN OBSERVATION PEN AREAS FOR AIRCRAFT SAMPLE NO. 16

Acentech Incorporated

Acoustical & Environmental Technologies

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APPENDIX C

TREATMENT SCHEDULE FOR OVERFLIGHT SIMULATION

AT THE UNIVERSITY OF ARIZONA, TUCSON, 1990-1991.

Start date	End date	Treatment description
Summer[a]		
21 May 1990	15 Jun 1990	Pre- treatment baseline
18 Jun 1990	24 Jun 1990	1 overflight simulation/day
25 Jun 1990	8 Jul 1990	7 overflight simulations/day
9 Jul 1990	15 Jul 1990	1 overflight simulation/day
16 Jul 1990	10 Aug 1990	Post- treatment baseline
Late summer		
13 Aug 1990	6 Sep 1990	Pre-treatment baseline
9 Sep 1990	15 Sep 1990	1 overflight simulation/day
16 Sep 1990	29 Sep 1990	7 overflight simulations/day
30 Sep 1990	6 Oct 1990	1 overflight simulation/day
8 Oct 1990	12 Oct 1990	Post- treatment baseline
Spring		
4 Feb 1991	28 Feb 1991	Pre- treatment baseline
3 Mar 1991	9 Mar 1991	1 overflight simulation/day
10 Mar 1991	23 Mar 1991	7 overflight simulations/day
1 Apr 1991	5 Apr 1991	Post- treatment baseline

[a] Summer = 12 May-9 Aug 1990, Late summer = 13 Aug-12 Oct 1990, Spring = 4 Feb-5 Apr 1991.

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